Derivation of an Initial Unit Hydrograph for the Sacramento Model

There are two basic methods for deriving an initial estimate of the unit hydrograph for use with the Sacramento model. The first is to use data from actual storm events for the watershed and the second is to use one of a number of techniques to derive a synthetic unit hydrograph. If the proper conditions exist it is much better to derive the unit hydrograph using actual storm data.

Derivation of a Sacramento Model Unit Hydrograph from Storm Events

The procedure to derive a Sacramento model unit hydrograph from actual watershed data involves separating the fast response runoff contribution, i.e. surface and impervious, from the other runoff components prior to doing the unit hydrograph computations. In order to do this the following conditions must be met:

- the storms used must produce a significant amount of fast response runoff,

- there must be a reasonably clean recession period for some time after each event, typically in order of several weeks, and

- the precipitation causing the storm response should occur within a few time intervals; all within one period is best, but up to 3 or 4 time intervals are okay (complex storms and snowmelt periods should be avoided as when deriving a traditional unit hydrograph).

In order to separate out the fast response runoff contribution so that the effect of the channel system and overland flow can be isolated, a recession analysis is used. The recession analysis should allow one to remove the baseflow and interflow contribution. This is analogous to separating out baseflow when deriving a traditional unit hydrograph only in this case the interflow contribution must also be removed. Once the watershed response to surface and impervious runoff is determined, then the remainder of the process is exactly the same as when computing unit hydrograph ordinates in the traditional case. If one is not familiar with these steps, they are described in many textbooks.

In order to perform a recession analysis, a semi-log plot is generated for the receding portion of the hydrograph. Such a case is shown in Figure 7-F-4. This figure contains an idealized case generated with synthetic data so that the steps in the procedure can easily be described. The steps in the recession analysis are:

- Identify the primary baseflow component if possible. This component will plot as a straight line on the semi-log plot after interflow and supplemental baseflow storages have been drained completely. In the figure, the plot is not extended all the way out to this point. Extend the primary baseflow contribution back to under the peak of the hydrograph and then subtract the primary flow component from the total flow. The result is shown as 'total - primary' in the figure.

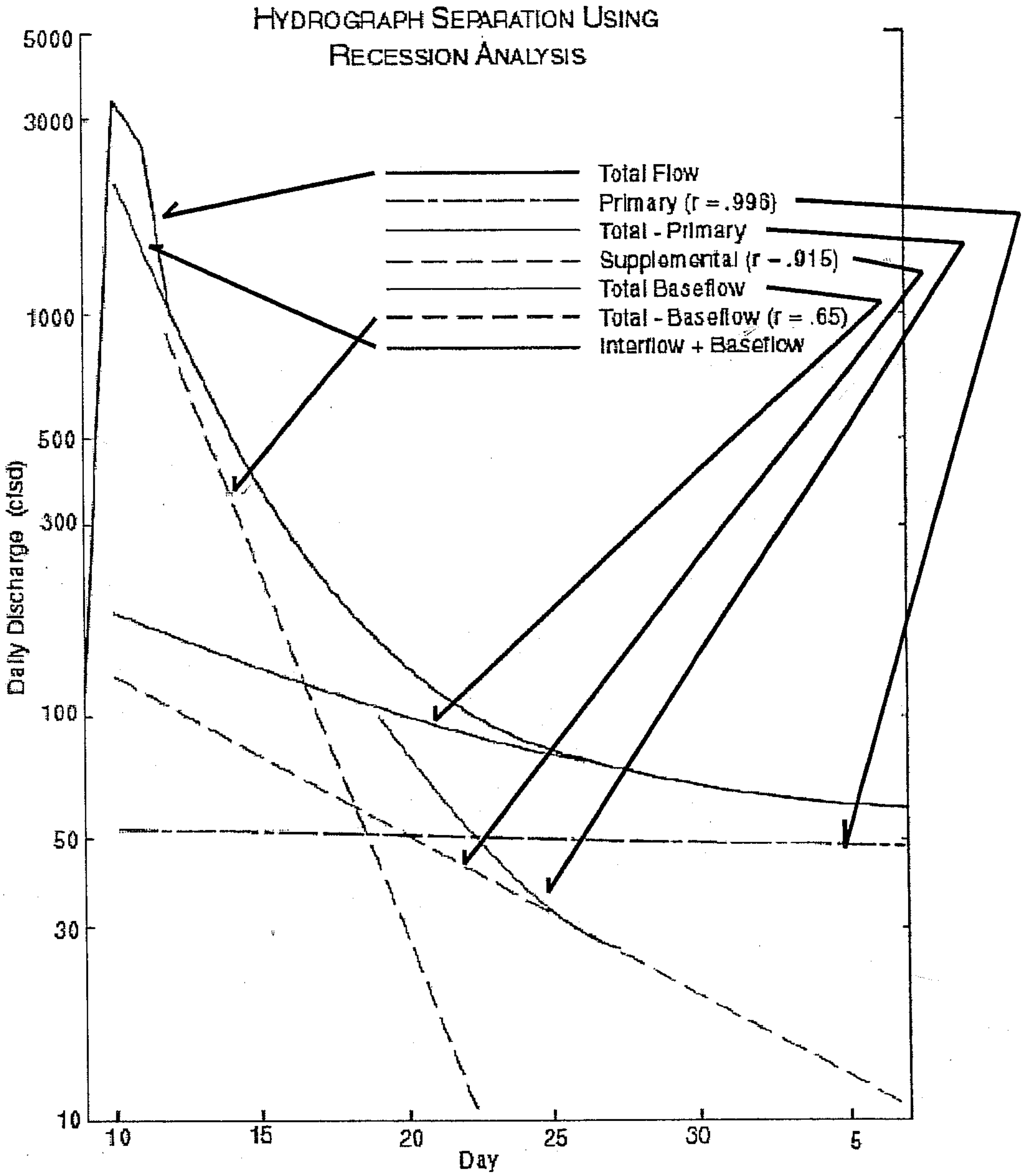

Figure 7-F-4. Illustration of a recession analysis using synthetic data.

• The straight line portion of the total minus primary line on the plot identifies the supplemental baseflow component. Extend the supplemental baseflow contribution back to under the hydrograph peak and then add the supplemental baseflow to the primary amount to get the total baseflow for this event. Then subtract the total baseflow from the total flow to get the 'total - baseflow' contribution. The total minus baseflow portion is shown on the plot starting at about the point where fast response runoff ceases though it could be extended back under the peak. In many real cases it is difficult to separate out primary and supplemental baseflow contributions, especially when the recession period is not very long or the supplemental withdrawal rate is quite slow. In these cases one would try to identify the total baseflow contribution, rather than dealing with primary and supplemental separately. The total baseflow recession will not plot exactly as a straight line on a semi-log plot since it is comprised of flow from two aquifers with different recession rates.

The 'total - baseflow' line will normally plot as a straight, or nearly straight, line on the semi-log plot. A recession rate can be computed for this segment. This is not the interflow recession rate, but instead an indication of how fast water is draining from the upper zone free water storage both as percolation and interflow. If soil moisture conditions are nearly saturated and this is a watershed with very low percolation rates under wet conditions, the amount of percolation should be small and thus, the total minus baseflow recession rate would be only slightly greater than the interflow recession rate and could be used to calculate an initial estimate of the Sacramento model UZK parameter. In most cases the 'total - baseflow' recession rate will be considerably greater than the interflow recession rate and can only be used as an extreme upper limit for UZK.

• The straight line portion of the 'total - baseflow' amount indicates the interflow contribution to the storm. This straight line segment is then extended back under the hydrograph peak and the total baseflow is added to the interflow contribution to obtain the amount of 'baseflow + interflow' for the event. This amount is only less than the total flow for a short time after the rain that produced the rise. During the remainder of the recession all the flow is either interflow or baseflow.

• The last step is to plot the total baseflow and the baseflow plus interflow amounts on an arithmetic plot as shown in Figure 7-F-5. Some subjectively is needed when drawing the recharge portion , i.e. the period from when the hydrograph starts to rise until these flow components start to recede. The upper zone free water storage and thus interflow should typically peak a time interval or two after the storm peak, while baseflow recharge generally will take longer and thus, the baseflow contribution will not peak until a day or two after the storm peak.

The sum of interflow and baseflow can then be subtracted from the total instantaneous discharge amount to get the fast runoff, i.e. surface plus impervious, contribution to the storm. The surface plus impervious discharge is then used to derive the unit hydrograph .

to be used with the Sacramento model using textbook methods

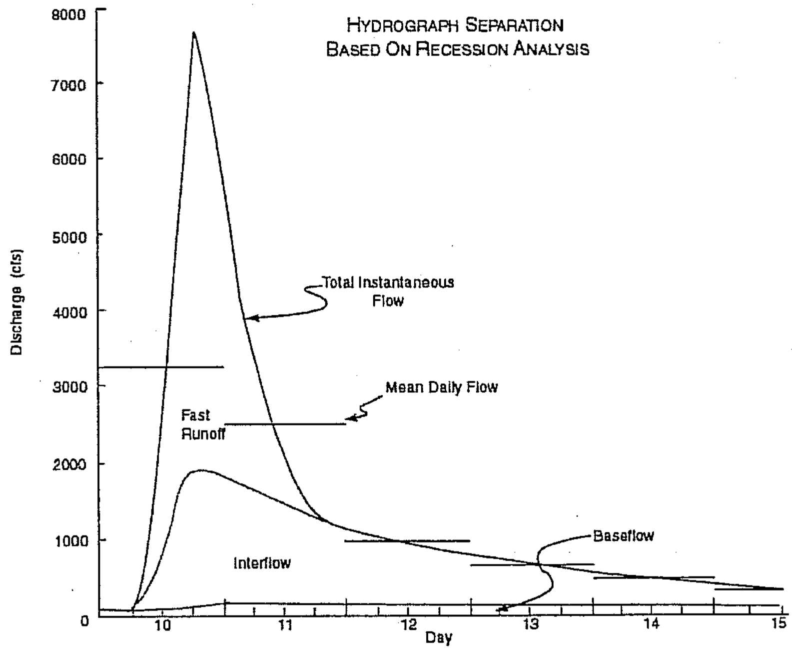

Figure 7-F-5. Separation of fast resonse runoff for deriving a unit hydrograph.

Figure 7-F-6 shows a recession analysis for an actual watershed. In this case there are several small events that occur in the period after the main storm, thus making it more difficult to determine the baseflow contribution. By looking at a low flow period further out in time than shown on the plot, the total baseflow contribution could be reasonably estimated. Then baseflow was subtracted from total flow to obtain the 'total - baseflow' amount and the straight portion of this line indicates the interflow contribution. 'Interflow + baseflow' was then computed and plotted for the storm event. Differences between total flow and 'interflow + baseflow' for the storm event that occur during the recession are the result of interflow and baseflow recharge from the subsequent small rainfall events. The total baseflow and 'interflow + baseflow' amounts are then plotted on an arithmetic plot shown as shown in Figure 7-F-7 to determine the fast runoff contribution to the storm hydrograph. Observed instantaneous discharge data were not available for this event so the total instantaneous flow was estimated by knowing the mean daily discharge amounts and the instantaneous peak flow. The rainfall for this event is also shown in the figure. The period of rain that generated most of the runoff was between 6 and 12 hours in length. Thus, the Sacramento model unit hydrograph computed from the fast runoff contribution to this event will be between a 6 and 12 hour unitgraph. An "S" curve analysis could be used to try and determine the appropriate time interval and then to compute a 6 hour unitgraph to be used with the model. If the storm event doesn't contain any fast response runoff, which was the case most of the time for the

Ellijay watershed (surface runoff only occurs 3 times during the period of record), then the recession analysis should show that the entire rise is primarily from interflow and the event can't be used to determine an estimate of the unit hydrograph to use with the Sacramento model. This occurs frequently in certain regions of the country.

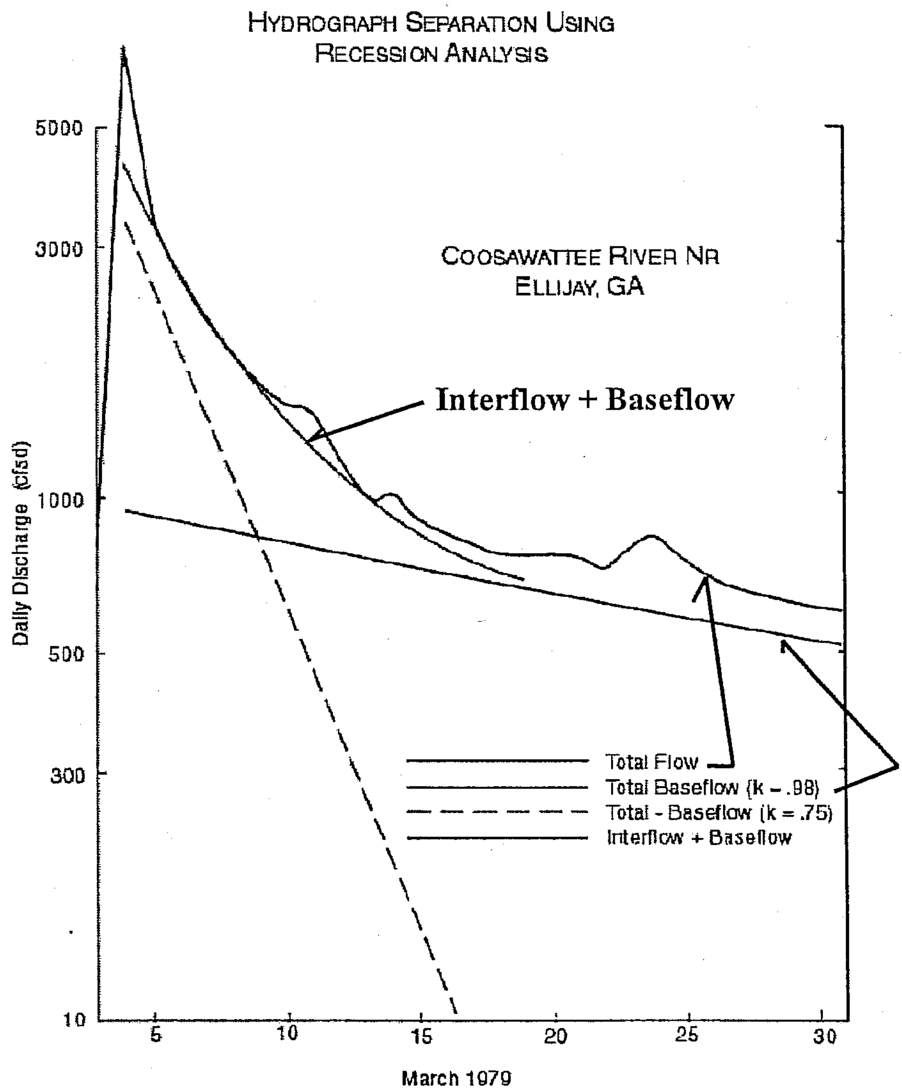

Figure 7-F-6. Recession analysis for the Ellijay watershed for March 1979 storm.

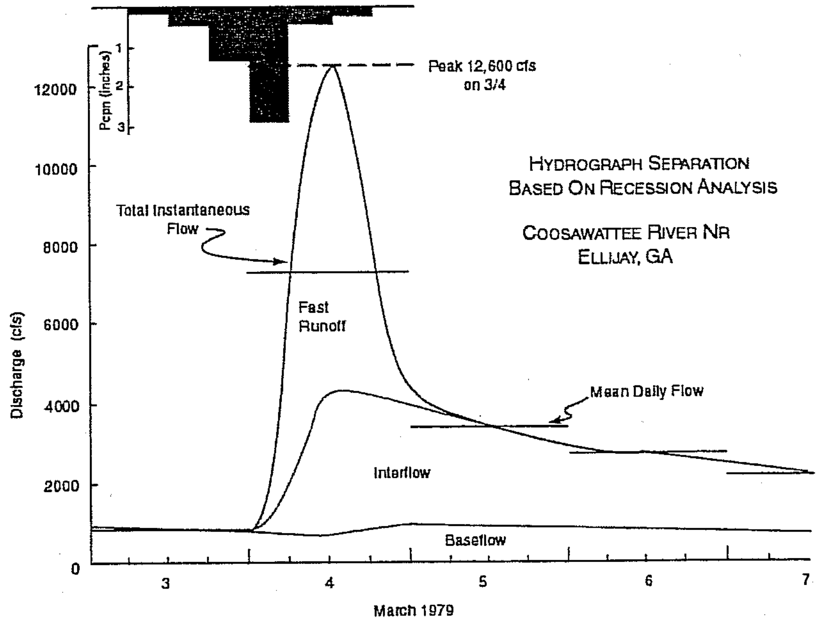

Figure 7-F-7. Fast runoff contribution to March 1979 storm for the Ellijay watershed.

Derivation of an Initial Unit Hydrograph using Synthetic Methods

If a unit hydrograph for use with the Sacramento model cannot be derived from precipitation and discharge data for the watershed, then there are a number of synthetic methods that have been proposed that are available. These methods generally fall into two categories. First there are time of travel methods which compute the portion of the watershed contributing each time interval based on travel time estimates. Second there are methods that use watershed geometry to estimate the peak discharge, the time to peak, and the base of the unit hydrograph. These methods contain coefficients that are determined from unit hydrographs derived from actual watershed data though in many cases the coefficients may only represent certain types of regions and could be more appropriate for an traditional, i.e. API model, unitgraph. In addition to using a synthetic method, in some cases it is adequate to subjectively estimate the initial unit hydrograph to use with the Sacramento model based merely on typical time to peak information for major events, though this requires a certain amount of experience.

This author is not an expert on synthetic methods for deriving a unit hydrograph. Thus this manual will not include a discussion of the pros and cons of each procedure. The only warning offered when using a synthetic method is for slower responding watersheds where the storm hydrograph doesn't typically peak until days, rather than hours, after the rainfall or